

Modal Radiation of Guided Waves by Finite-Sized Sources in a Semi-Infinite Multi-Layered Anisotropic Plate

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Modal decomposition of guided waves (GW) in anisotropic multi-layered plates is helpful to interpret signals measured in GW NDE methods for testing composite materials. Simulation tools of GW NDE examinations are developed notably to provide help for interpretation. Thus, models on which they rely can provide an even greater help if they predict the various phenomena involved in terms of modal amplitudes. Most GW sources being of finite size, diffraction effects occur. Plate-like structures to be tested being of finite size, edge reflection with mode-conversion occurs too. A model is proposed to predict the field radiated in a semi-infinite multi-layered anisotropic plate which accounts for both the diffraction effect and the reflection at an edge.

At first, modes in an arbitrary multi-layered anisotropic plate are computed thanks to the Semi-Analytical Finite Element (SAFE) method as implemented in CIVA software platform developed at CEA [1]. Then, a model for the calculation of the field radiated in an infinite plate by a finite-sized source was recently derived [2] making use of the modal solution computed by means of the SAFE solver. In this model, the integration over the finite size of the source is computed thanks to a change of variable of integration: the surface integral (2D) is replaced by an angular integral (1D) over angles of energy paths between the field point and the source surface. This method was shown to efficiently reproduce results obtained by means of surface integral convolution of the source with the 3D Green's function. Special care was taken to consider the fact that, for some modes in anisotropic materials, one energy direction may be associated to more than one phase direction.

Here, the same approach is extended to account for reflection on a free boundary of the plate. This is done by combining the energy path approach to the model presented in [3] for reflection at the edge of an isotropic plate. Two separate problems must be solved. The first consists in finding energy paths between the source and a field point when reflection occurs, before proceeding to angular integration. This is formally easy but details will be given to explain how to proceed efficiently. The second problem consists in computing reflection coefficients to be associated to the energy paths previously determined. For this, a system quite similar to SAFE system is formed to compute all the modes of wave-vector component parallel to the edge equal to that of the incident energy considered. This allows us to build a last system in which boundary conditions are introduced to obtain reflection coefficients. Thus, the complex mode-conversion phenomena arising at edges of anisotropic plates are fully taken into account. Interestingly, the concept of integration over energy paths extended herein to reflection is formally of the same nature as the overall pencil approach described in [4]: multiple reflections could be treated within the same theoretical framework.

References:

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